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NPL
National Physical Laboratory

Supplementary comparison CCRI(I)-S2 of standards for absorbed dose to water in ^{60}Co gamma radiation at radiation processing dose levels

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Introduction

Eight national standards for absorbed dose to water in ^{60}Co gamma radiation at the dose levels used in radiation processing have been compared over the range from 1 kGy to 30 kGy using the alanine dosimeters of the NIST and the NPL as the transfer dosimeters. The comparison took place in 2009 and was organized by the Bureau International des Poids et Mesures, who also participated at the lowest dose level using their radiotherapy-level standard for the same quantity. We present here a brief description of the comparison and its results, further information can be found in [1]. The participating countries were China, Czech Republic, Denmark, France, Italy, Russian Federation, United Kingdom and United States.

Comparison procedure

The agreed protocol required each national laboratory to send information on its irradiation procedure to the NIST and the NPL (via the BIPM) in advance of the irradiations. Each laboratory was sent eleven alanine transfer dosimeters from the NIST and eleven from the NPL. Of each set of eleven, two were irradiated to each of four nominal dose levels: 1 kGy, 5 kGy, 15 kGy and 30 kGy (note that, in order that the comparison remained blind, laboratories were instructed to give doses in the region of, but not precisely equal to, the nominal dose levels). Of the three remaining control dosimeters for each set, two were irradiated before issue (to 1 kGy and 15 kGy) and the third remained unirradiated. For the BIPM, a similar arrangement was used, but because of the low dose rate of the reference ^{60}Co radiotherapy-level field at the BIPM irradiations were only feasible for the 1 kGy dose level.

Irradiations at all laboratories took place in the three-week period beginning 9 February 2009. The dosimeters were returned immediately to the issuing laboratories with information on irradiation temperatures but no information on dose estimates. All laboratories sent their irradiation dose estimates to the BIPM for analysis, along with information on the basis of the dose and uncertainty estimates. The issuing laboratories sent their measured alanine doses to the BIPM by the end of April 2009.

The irradiation geometry was not specified in detail in the protocol; each irradiating institute used their normal arrangement. This policy was adopted so that the dose estimates be representative of those routinely disseminated by each institute, rather than modified for the purpose of the present comparison. All laboratories other than the ENEA-INMRI, CMI-IIR, NIM and the BIPM employed a laboratory-scale self-shielded irradiator. The ENEA-INMRI irradiated the dosimeters in a large pool-type irradiation facility and the CMI-IIR in a small industrial facility. The NIM and the BIPM irradiated the alanine dosimeters in a water phantom under their reference conditions in ^{60}Co.

Results

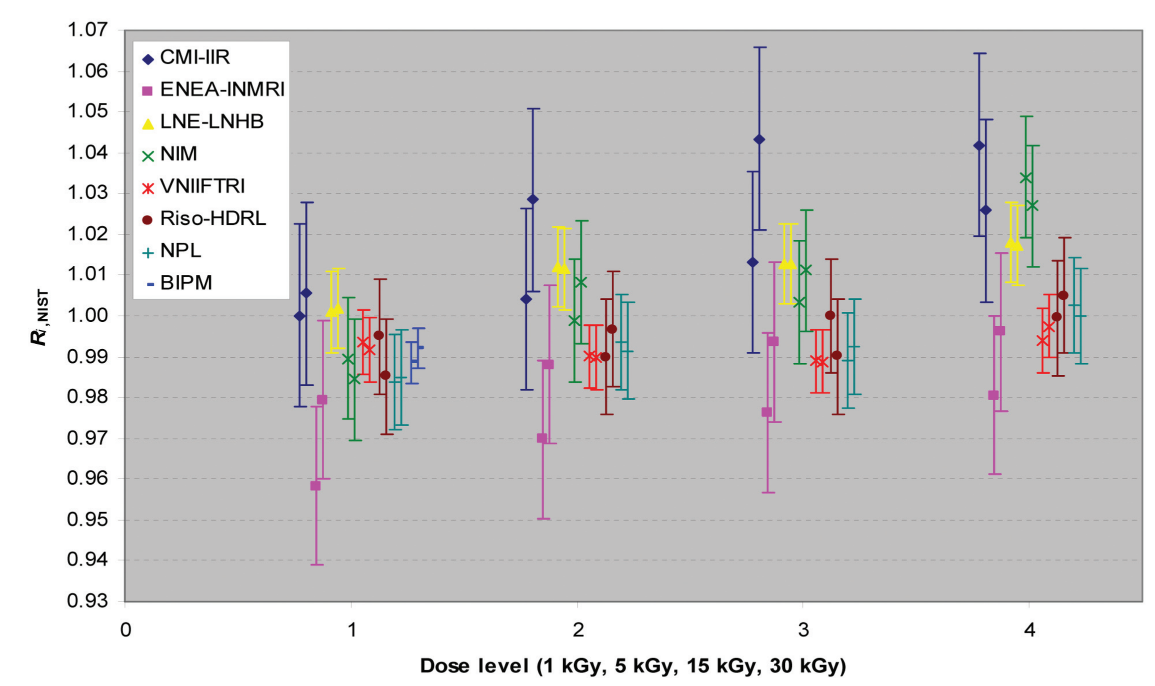

Figure 1. Comparison results using the NIST alanine transfer dosimeters, expressed as the ratio R_i,NIST of the dose estimate of the irradiating laboratory relative to that of the NIST, for the four stated dose levels. The uncertainty bars represent the combined standard uncertainty of the laboratory dose estimate and the reproducibility of the NIST alanine dosimeter (0.4 %).

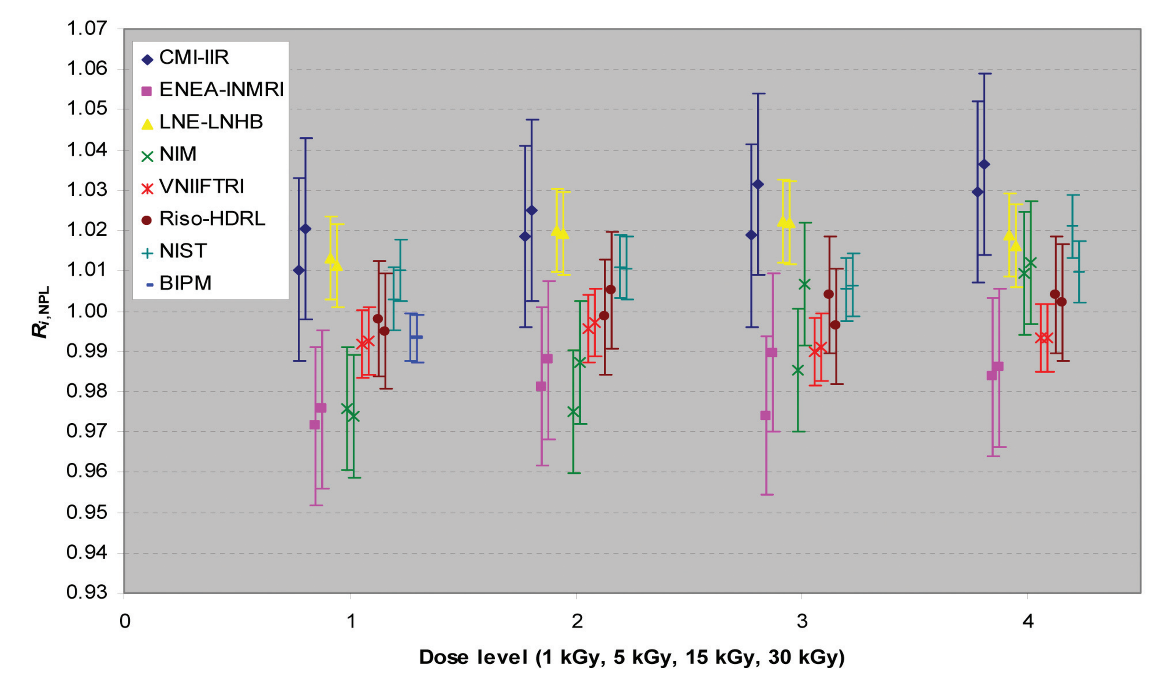

Figure 2. Comparison results using the NPL alanine transfer dosimeters, expressed as the ratio R_i,NPL of the dose estimate of the irradiating laboratory relative to that of the NPL, for the four stated dose levels. The uncertainty bars represent the combined standard uncertainty of the laboratory dose estimate and the reproducibility of the NPL alanine dosimeter (0.5 %).

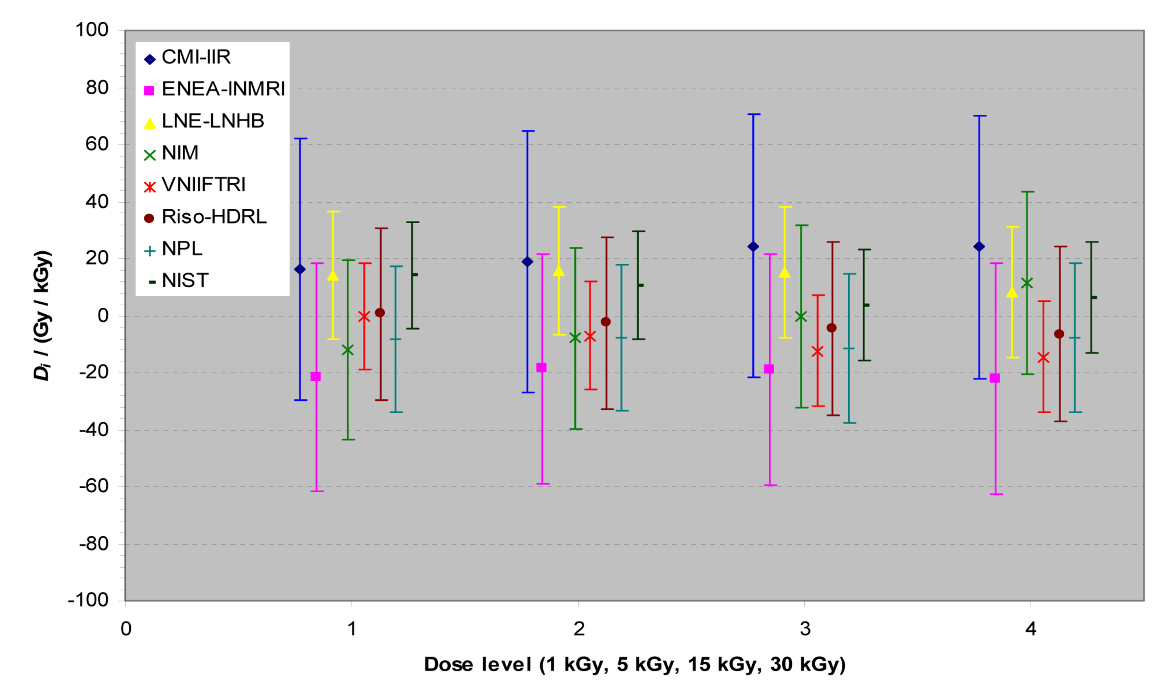

Figure 3. The normalized differences D_i, in Gy per kGy, with respect to the reference value for the comparison, for each laboratory and each dose level. The uncertainty bars represent the expanded uncertainty U_i of these differences (with coverage factor $k = 2$).

Discussion

The results demonstrate that the national high-dose standards of the participating laboratories are in general agreement within the standard uncertainties, which are in the range from 0.7 % to 2.2 %.

Nevertheless, for those laboratories with an absorbed-dose rate that is low in relation to the dose rate at which the alanine dosimeters are calibrated, there is evidence of a trend in the results with dose level. This effect has been seen in previous work [2] and is demonstrated by the analysis presented in Figure 4. Here, the parameter *S* for each laboratory represents the slope, in percent per kGy, of the values for R_i,NIST from Figure 1, and separately for R_i,NPL from Figure 2, as a function of the irradiation dose. These values for *S* are plotted as a function of the irradiation dose rate relative to the alanine calibration dose rate. While the use of simple linear fits over the range from 1 kGy to 30 kGy to derive values for *S* is appropriate in view of the statistical uncertainties, it should not be inferred that the effect continues linearly at higher dose levels.

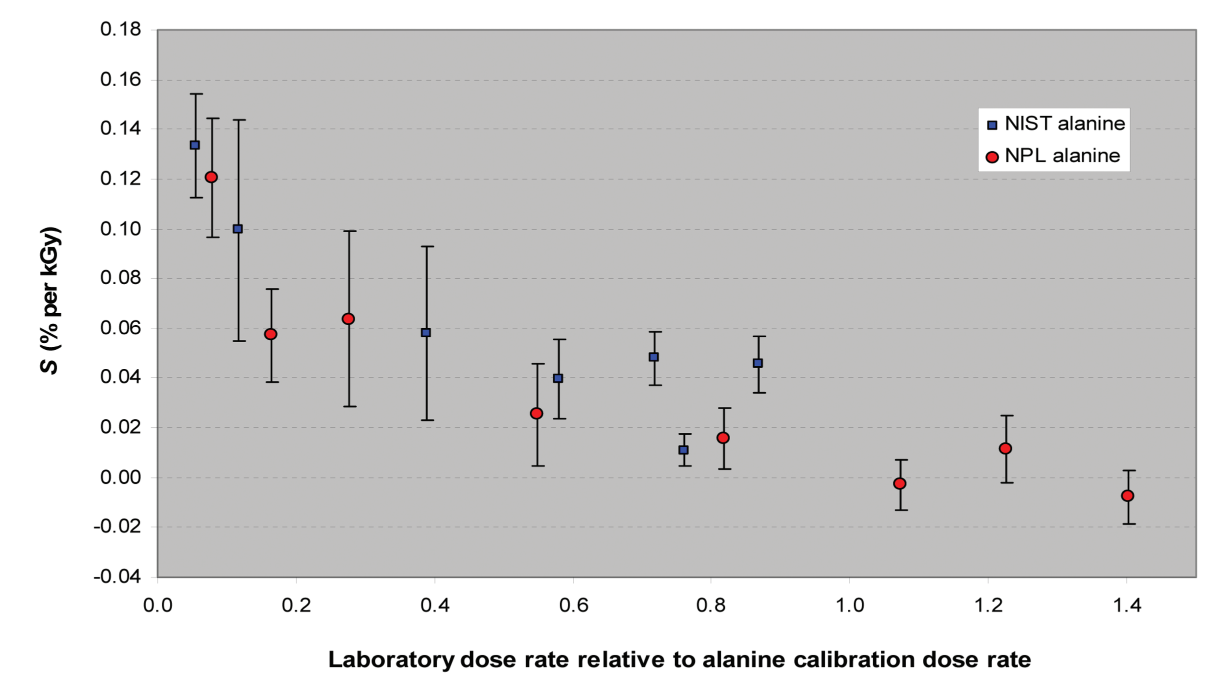

Figure 4. The slope S of the laboratory results R_i,NIST and R_i,NPL as a function of irradiation dose, plotted with respect to the laboratory dose rate relative to the alanine calibration dose rate. The uncertainty bars represent the standard uncertainty of S resulting from the linear regression. The results of the NIST irradiations of the NPL alanine at two dose rates are shown as separate points.

It is clear from Figure 4 that a systematic effect is present, although the statistical uncertainties do not permit one to distinguish the functional form of the effect.

Conclusion

Eight national standards of absorbed dose to water in ^{60}Co radiation at radiation processing dose levels have been compared and found to be in general agreement within the standard uncertainties.

The demonstrated equivalence of national standards is an essential component of the CIPM Mutual Recognition Arrangement [3], which facilitates the mutual recognition of dosimetry standards in the highly regulated radiation processing industry.

National
Measurement
System

References

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[2] M F Desrosiers, J M Puhl and S L Cooper, 2008, An absorbed-dose/dose-rate dependence for the alanine-EPR dosimetry system and its implications in high-dose ionizing radiation metrology J. Res. NIST 113 79–95

[3] 1999 Mutual Recognition of National Measurement Standards and of Calibration and Measurement Certificates Issued by National Metrology Institutes (CIPM MRA) (Sèvres, France: Comité international des poids et mesures)

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